Topic 2.8.2: CCLME - Pinnipeds

California sea lions:
Sentinel Species for California Current Integrated Ecosystem Assessment

AFSC, MML, California Current Ecosystem Program

Sharon Melin, Jeff Laake, Robert DeLong

SWFSC, ERD

Isaac Schroeder

18-22 April 2016

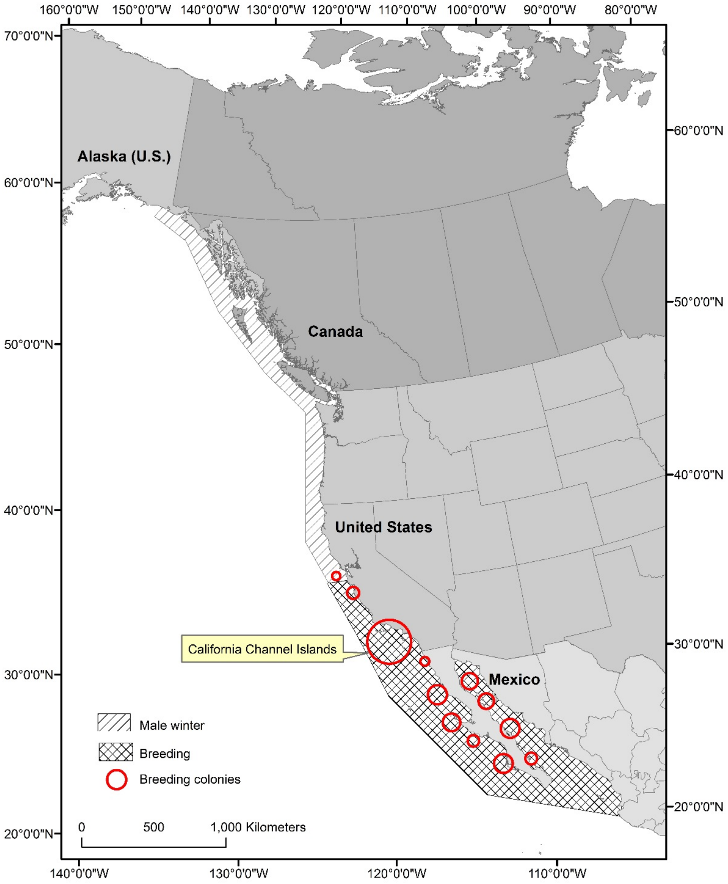
Terms of Reference Questions

4. Status of oceanographic, habitat, climate, and ecological data needed for ecosystem-related science needs

5. Cumulative and integrative analysis and modeling of ecosystem-level processes

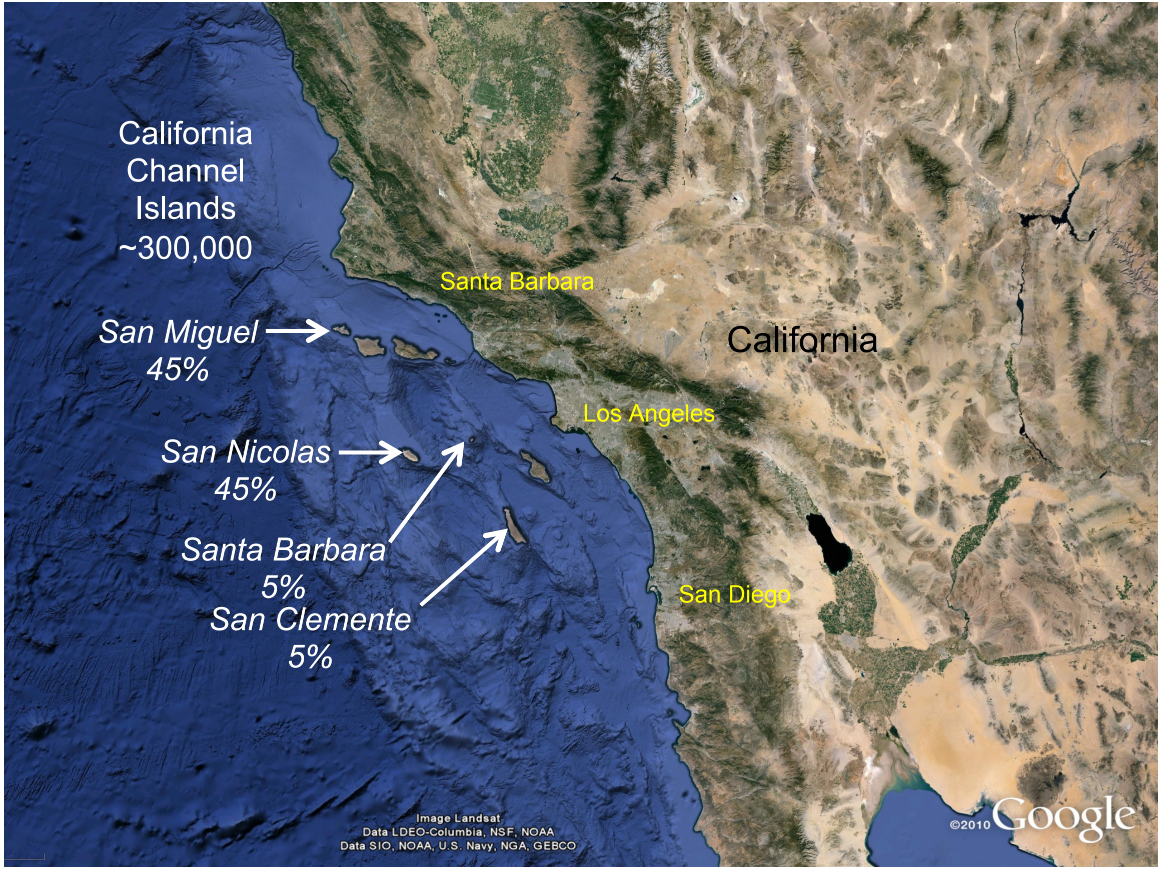
California sea lion Distribution

- All at breeding areas summer (May – Aug)
- Males migrate to northern CCS and Alaska in winter (Sep – Apr)
- Females resident in central and southern CCS year round



California sea lion Distribution

- U.S. population breeds mostly in Channel Islands
- 90% breeds at San Miguel and San Nicolas Islands
- San Miguel and San Nicolas good index sites



Ecological Data for Ecosystem Science: California sea lion Research Program

1. Annual counts of live and dead pups provide trends in births and mortality for population status
2. Annual sampling and weighing for trends in health, condition and growth
3. Annual estimates of survival and natality from long-term mark-resighting study using branded individuals
4. Annual scat collection provides index of diet
5. Satellite telemetry describes foraging distribution and behavior – 2 years, every 5-10 years

Ecological Data for Ecosystem Science: California sea lion Research Program

1. Annual counts of live and dead pups provide trends in births and mortality for population status
2. Annual sampling and weighing for trends in health, condition and growth
3. Annual estimates of survival and natality from long-term mark-resighting study using branded individuals
4. Annual scat collection provides index of diet
5. Satellite telemetry describes foraging distribution and behavior – 2 years, every 5-10 years

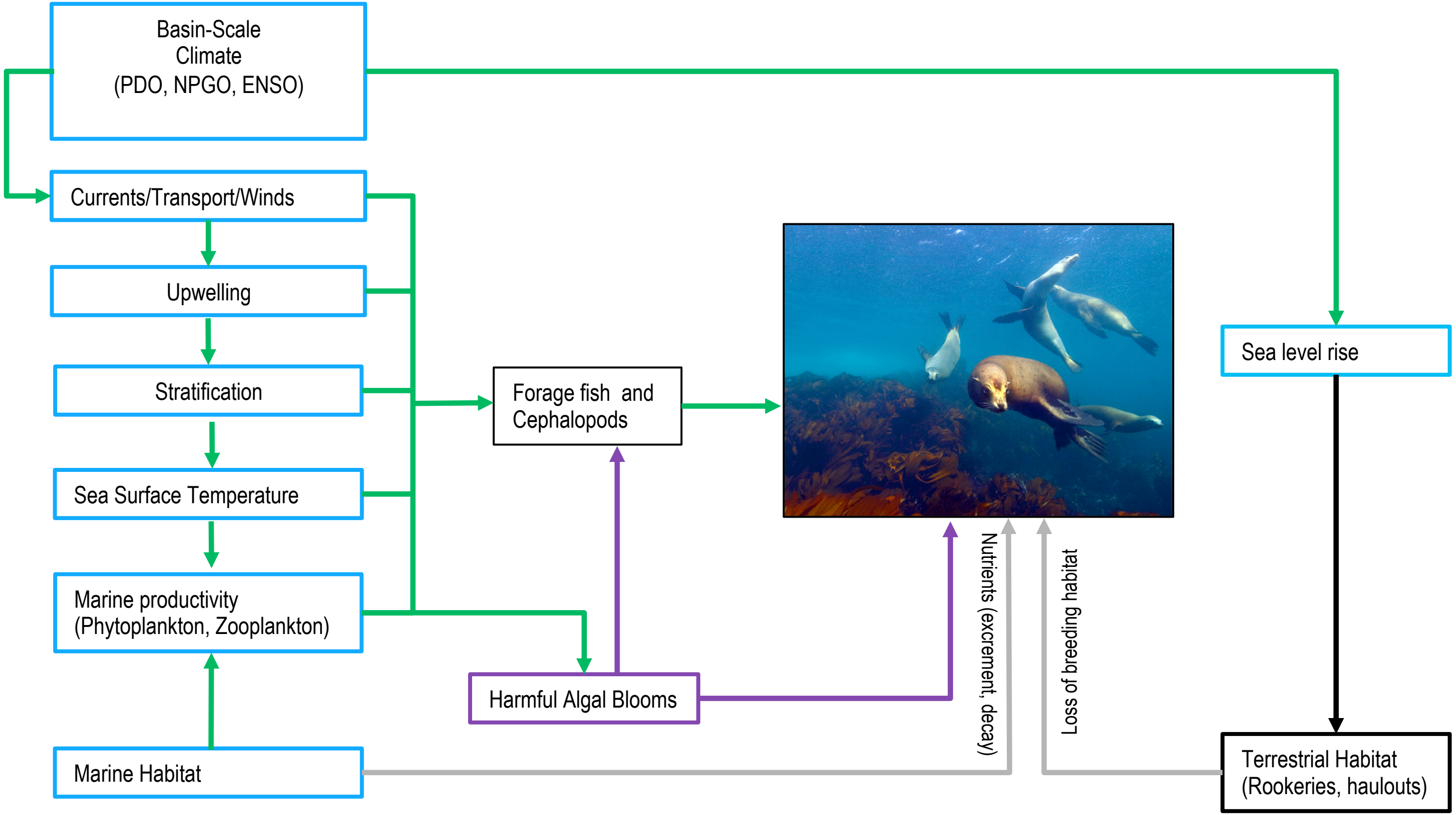
California sea lions Integrate Ecosystem Components

Environmental Drivers
- Regime shifts in physical/biological characteristics
- Annual/multi-year changes in local conditions
- Sea level rise

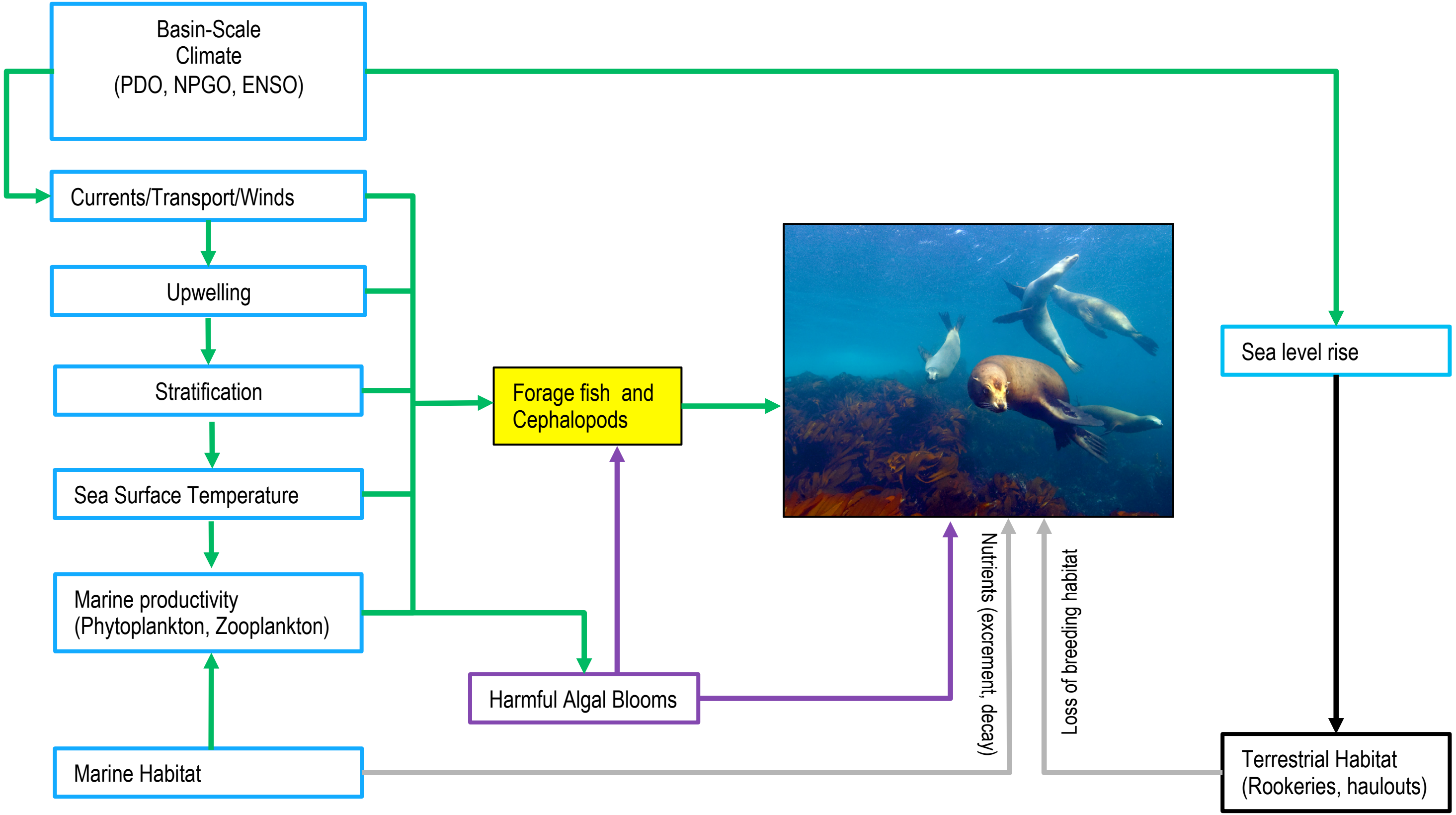
Ecological Interactions
- Consumption of economically important taxa
- Consumption of ESA listed fishes
- Exposure to HABs and terrestrial diseases

Human Activities
- Aesthetic value
- Fishery and nuisance interactions
- Coastal development
- Pollution

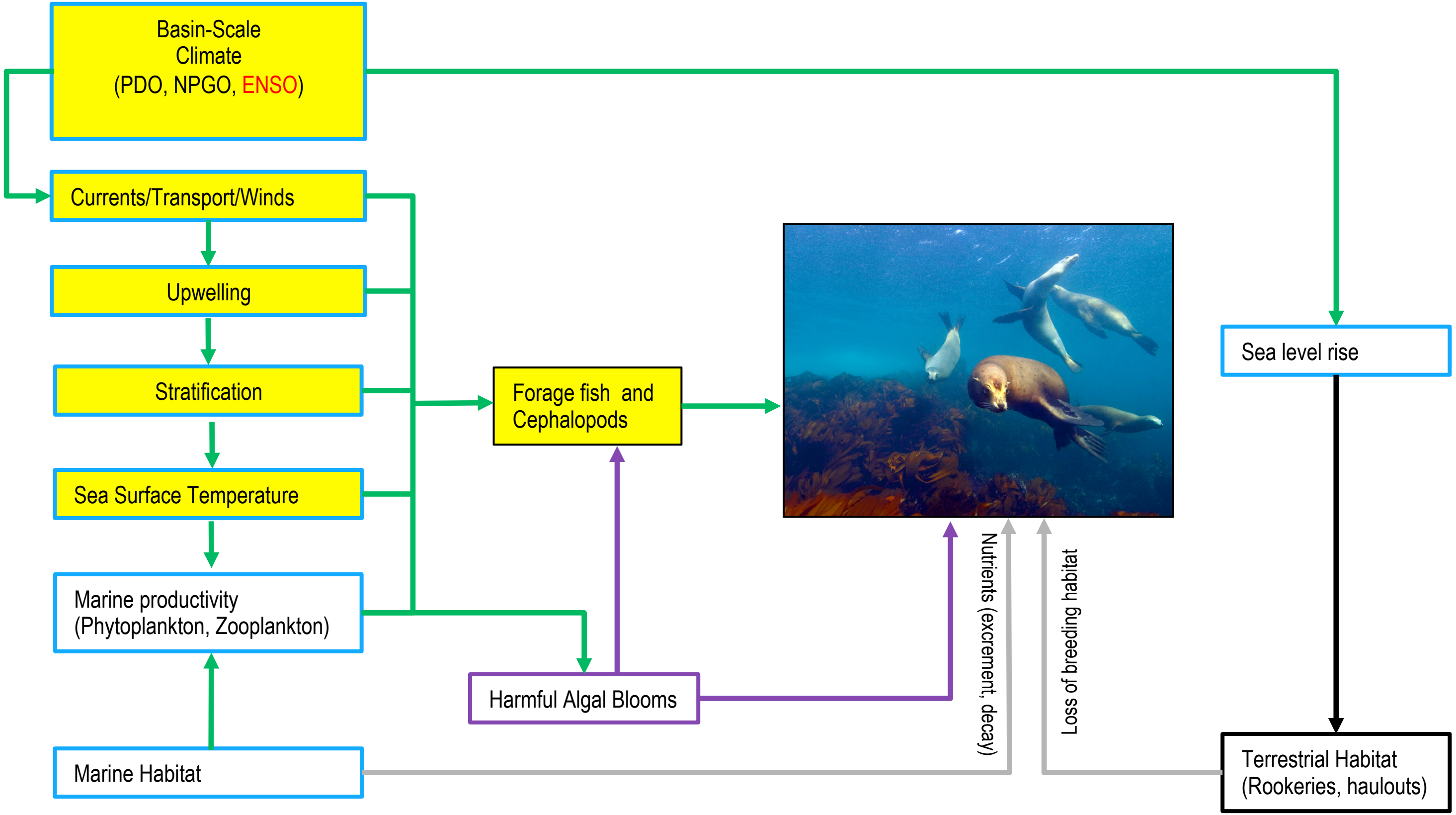
California sea lions Integrate Ecosystem Components: Environmental Drivers



California sea lions Integrate Ecosystem Components: Environmental Drivers



California sea lions Integrate Ecosystem Components: Environmental Drivers

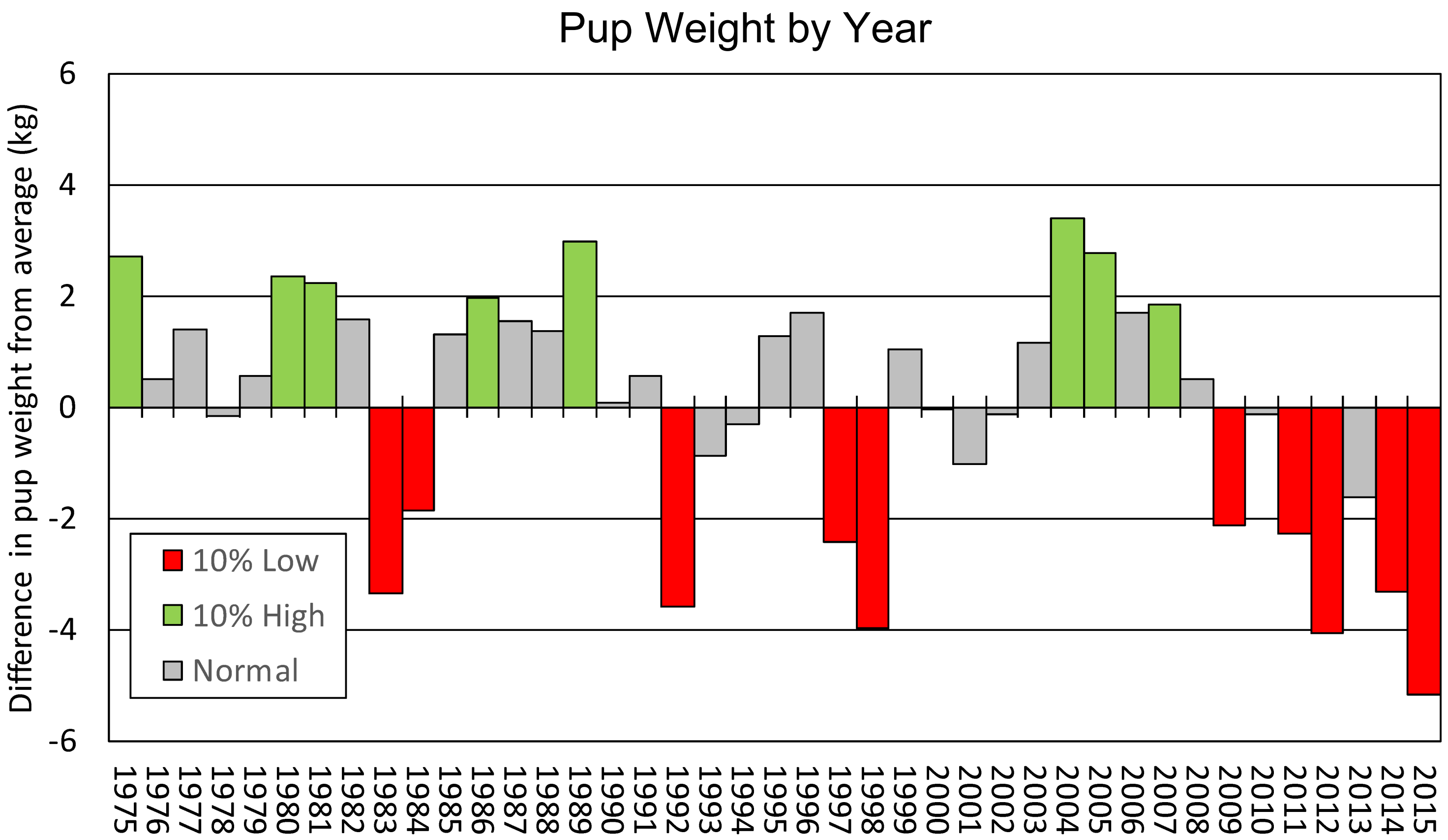


Modeling Ecosystem Relationships: Environment, Fish Biomass, Female Diet and Pup Growth

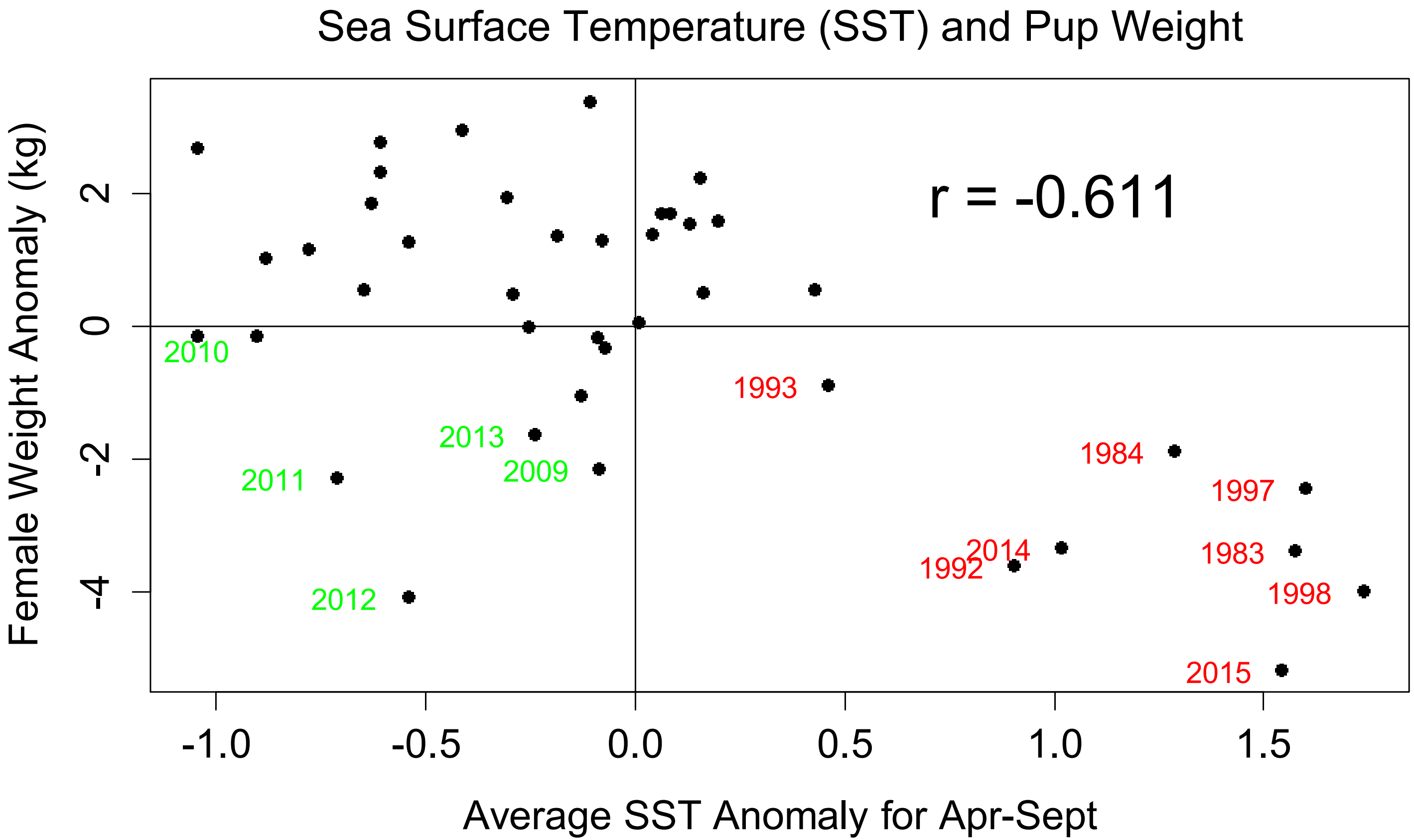
Modeling trends in pup growth

- 41 years of pup growth from 3 to 7 months of age; annually variable
- Linear mixed-effects models
  - Environmental variables
    - 41 years - Multi-variate ENSO Index, sea surface temperature, upwelling index and sea level height from NOAA sources
    - 30 years - dynamic height, stratification, pycnocline depth, temperature at 75 m, oxygen at 75 m, nitrate at 75 m averaged over seven CalCOFI stations
  - Fish biomass from stock assessments for sardine, anchovy, hake
  - Diet of adult females during the period of pup growth as measured by frequency of occurrence in scats for 20 years

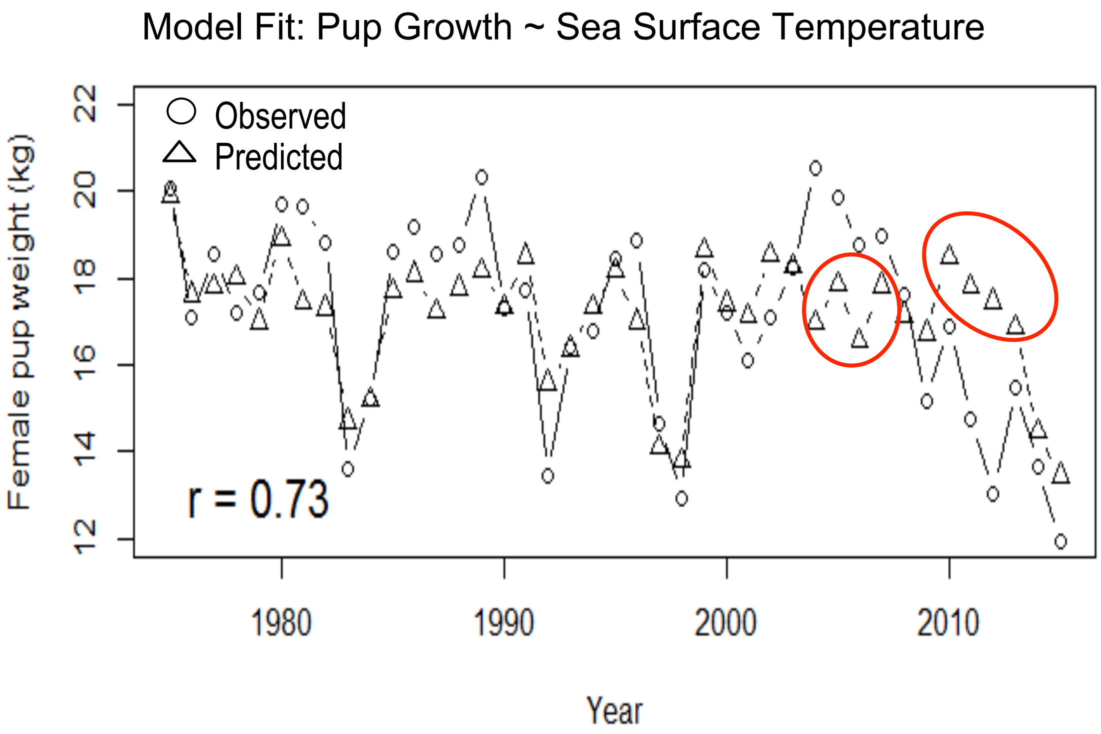
Modeling Ecosystem Relationships: Environment, Fish Biomass, Female Diet and Pup Growth



Modeling Ecosystem Relationships: Environment, Fish Biomass, Female Diet and Pup Growth

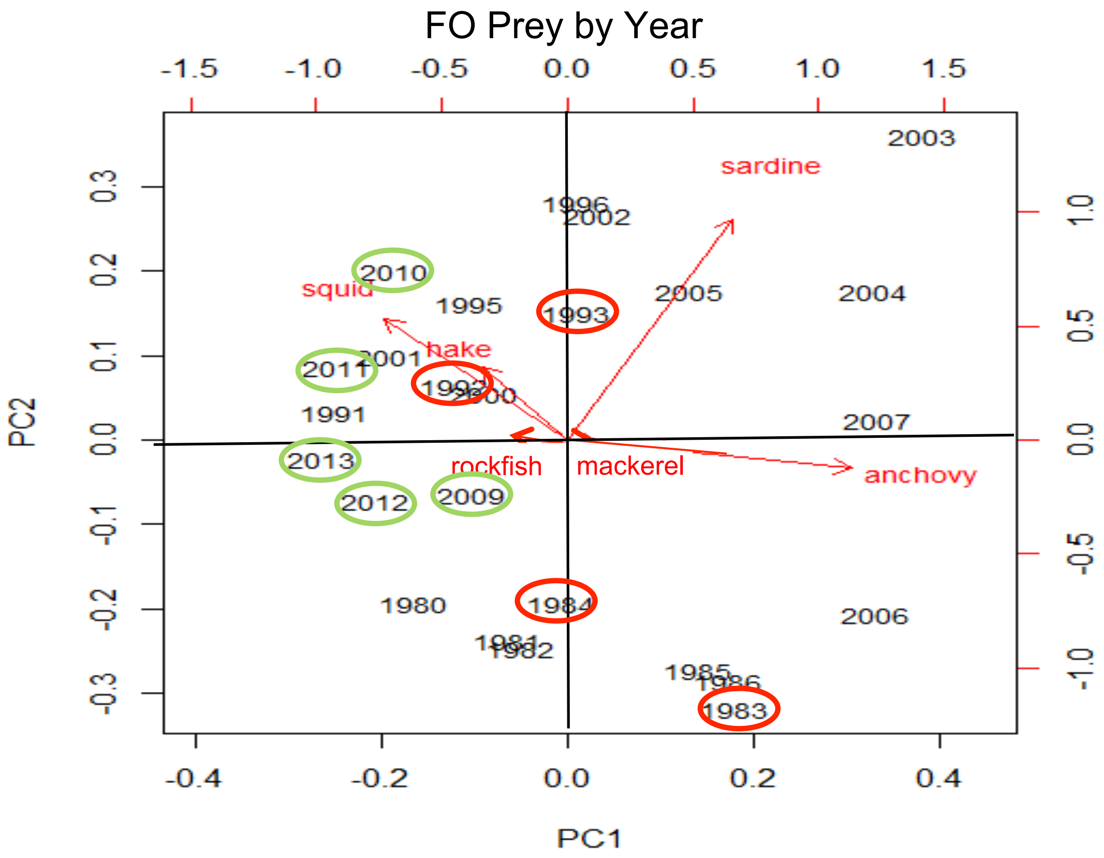


Modeling Ecosystem Relationships: Environment, Fish Biomass, Female Diet and Pup Growth

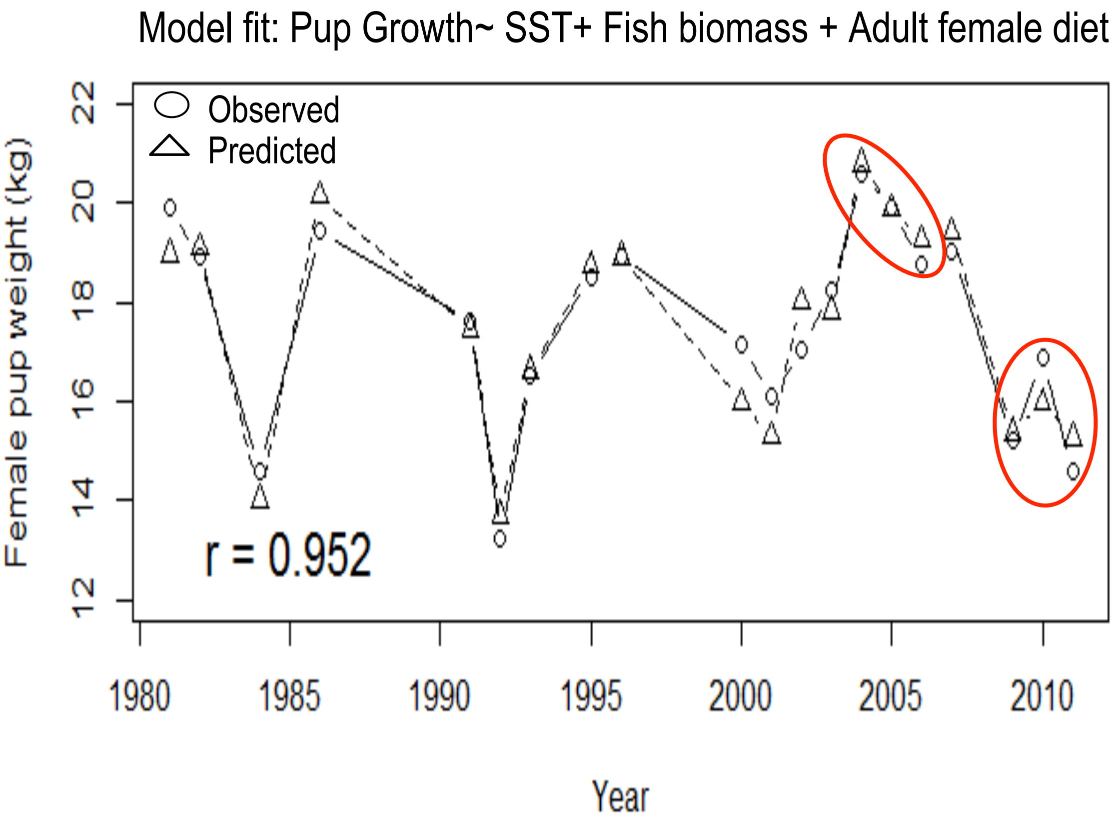


- 41 years
- SST negative relationship on initial weight and growth rate
- Declining trend in weights

Modeling Ecosystem Relationships: Environment, Fish Biomass, Female Diet and Pup Growth



Modeling Ecosystem Relationships: Environment, Fish Biomass, Female Diet and Pup Growth



- 20 years, non-consecutive
- SST negative relationship with initial weight and growth rate
- Sardine/anchovy biomass positive relationship
- Frequency of occurrence of rockfish negative relationship

Modeling Ecosystem Relationships: Environment, Fish Biomass, Female Diet and Pup Growth

Strengths

- Long-term monitoring datasets provide context to evaluate trends in population and environment
- Pup condition and adult diet are sensitive, reliable measures to detect changes in environment
- Long-term diet dataset from scats allows for trend analyses of specific prey species and sizes of prey
- Predictable access to all age/sex groups
- Cost-effective

Challenges

- Spatial and temporal mismatch in prey data
- Prey biomass not available for all prey species
- Only full-scale program at San Miguel but dynamics colony-specific

Solutions

- Coordinate/collaborate with oceanographers, fisheries biologists to analyze data or design surveys with predators in mind
- Expand studies for intra-colony comparisons

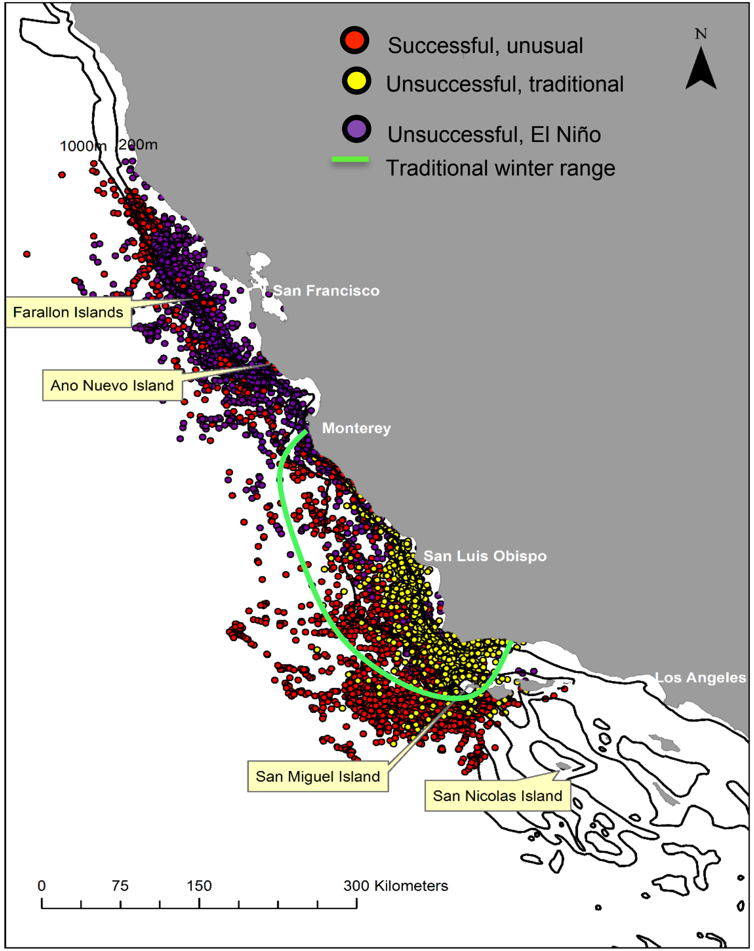
Modeling Ecosystem Relationships: Environment and Foraging Ecology using Satellite Telemetry

Modeling habitat use

- Spatially link dive behavior variables with predicted locations
- Combine with categorical and continuous predictor variables in linear mixed-effects models:
  - individual, month, year, season
  - static environmental: bathymetry, slope, distance to nearest rookery, distance from coast
  - dynamic environmental: SST, wind speed, chlorophyll-*a* (Aqua MODIS), sea surface height (AVISO), prey distribution (SWFSC/NWFSC Trawl surveys, CDFG CPUE)

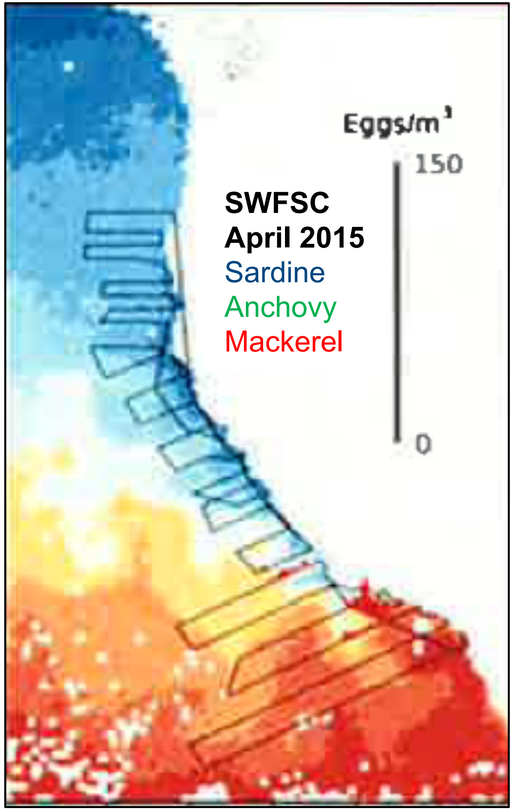
Modeling Ecosystem Relationships: Environment and Foraging Ecology using Satellite Telemetry

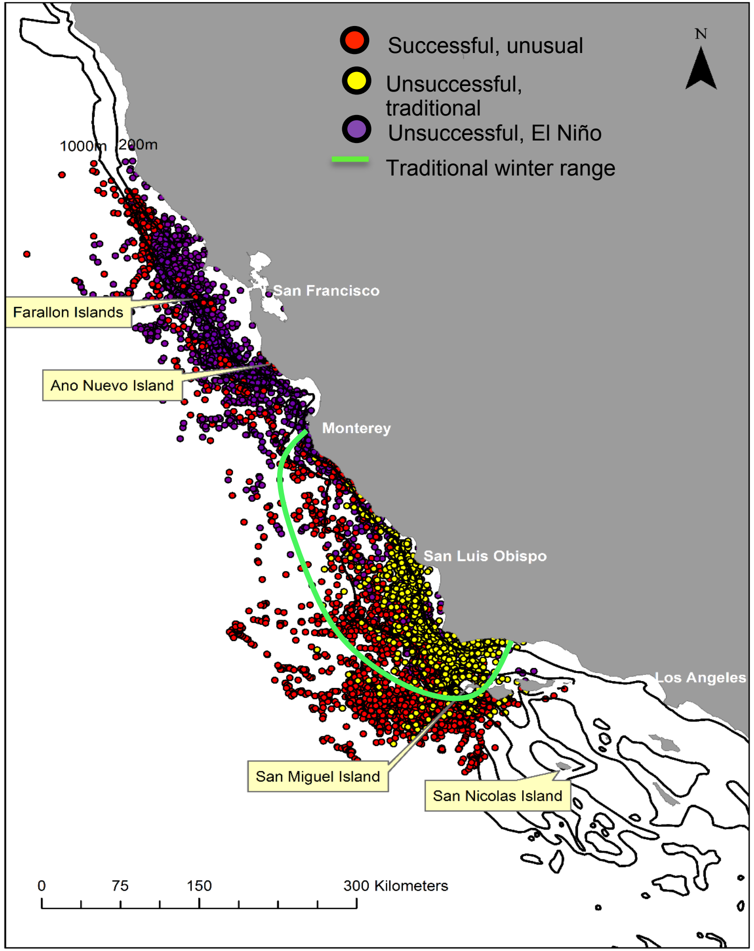
- **12 nursing females tagged with satellite tags December 2014-April 2015**
- **Successful Nursing Females**
  - 4/5 (80%) raised pups to weaning in March/April
  - Short trips of 2-3 days with less than one day nursing
  - Deep diving over 400 m; feeding on large hake and squid
  - Significantly larger females (91.1 kg average)
- **Unsuccessful Nursing Females**
  - Failed to rear pup past February 2015
  - 4 females used traditional area; 3 used northern area
  - Traditional attendance (3-4 days) or longer foraging trips
  - Mostly shallow to 75 m and diel pattern with some deep diving
  - Significantly smaller females (82.2 kg average)
- Pups not different in initial weight in two groups
- Some overlap after pups weaned, 3 successful females moved to northern area others continued to use southern area



Modeling Ecosystem Relationships:
Environment and Foraging Ecology using Satellite Telemetry

- Very warm conditions in CCS reduced availability of sea lion prey
- Extremely low abundance of anchovy and sardine in foraging range
- Low abundance of mackerel near islands may have been important for successful females along with hake found in enema/scat contents
- Under such conditions, larger females have more options and show potential for adaptation to a changing CCS





Modeling Ecosystem Relationships: Environment and Foraging Ecology using Satellite Telemetry

Strengths

- Satellite telemetry and biological sensing instruments provide integration of animal behavior and environment in near real-time
- Habitat use can be integrated with static or dynamic environmental features
- Enemas and scats from instrumented individuals link behavior with diet
- Sea lions as biological samplers can provide new information on ecosystem components (e.g., location of prey in winter)

Challenges

- Statistically robust sample sizes across population limited by logistics and instrument costs
- Spatial mismatch between prey surveys/ biomass estimates and telemetry data
- Quantity of data collected from instruments is large and computationally intensive, time-consuming to analyze

Solutions

- More collaborations with other entities to increase sample sizes/ age groups/ecosystem regions
- Collaborate with oceanographers, fisheries biologists to analyze data or design surveys to assess prey availability for predators
- Software is quickly catching up; train staff to use it